Analysis of Physical Processes and Riparian Habitat Potential of the San Joaquin River

Friant Dam to the Merced River

San Joaquin River Riparian Habitat Restoration Program

Participants:

Friant Water Users Authority
Natural Resources Defense Council
Pacific Coast Federation of Fisherman's Associations
U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service

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October 1998

This document should be cited as:

Jones & Stokes Associates, Inc. 1998. Analysis of physical processes and riparian habitat potential of the San Joaquin River—Friant Dam to the Merced River. October. (JSA 97-303.) Sacramento, CA. Prepared for U.S. Bureau of Reclamation, Fresno, CA.

Summary

This document presents an analysis of how physical processes, such as flow conditions and sediment regimes, have shaped the San Joaquin River and affected the patterns of riparian habitat along 150 miles of the river from Friant Dam to the confluence with the Merced River. The study area has been divided into seven subreaches on the basis of geomorphological characteristics of the valley and river as well as hydrological changes that have been imposed on the river network since the turn of the century (Table 1.1, Figure 1.1, and map in Appendix A.)

The study objectives are to:

- ✦ describe and analyze the physical processes affecting the San Joaquin River in the study area;
- ✦ determine how physical processes affect the distribution of riparian vegetation;
- ✦ understand how riparian vegetation is constrained or promoted by physical conditions and current river management; and
- ✦ recommend feasible approaches to the future expansion or enhancement of riparian habitat.

Study Methods

Two low-altitude aerial reconnaissance flights were conducted in fall 1997 to record channel planform, important geomorphic and hydrologic features, and vegetation patterns. Ground level surveys of the study area were conducted to collect sediment samples and record observations of physical processes and channel geometry; record vegetation structure, condition, dominant species, and relation of species to channel geometry; and observe apparent limiting factors for existing vegetation and for potential future restoration efforts. Color photographs taken to record observations during aerial and field reconnaissance surveys are contained in Appendix B, with informative captions.

The pre-Friant Dam morphology of the San Joaquin River and sloughs was assessed based on the California Debris Commission's (CDC's) 1914 topographic and hydrographic survey of the San Joaquin River and its floodplain, basins, and sloughs.

Fourteen cross sections were selected to represent the geomorphic conditions in the study reach (Appendix A). Twelve of the 1914 cross sections were subsequently resurveyed in spring 1998 and compared for changes in channel geometry and other morphometric features, such as thalweg profiles and width-to-depth ratios. Nine cross sections between RM 234.4 and RM 266.6, originally surveyed by the U.S. Bureau of Reclamation in 1939 and subsequently resurveyed in 1996 by Cain (1997) were used to evaluate changes in this reach.

Sources of hydrologic data used to develop information for the study include previous peak flow analyses by the U.S. Army Corps of Engineers (Corps) (1993, 1997), Cain (1997), and The Bay Institute (1997). Peak flow frequency information was estimated for pre- and post-Friant periods from several sources of gaging station data. Flow duration curves were developed from mean daily flows for nine gaging stations.

Existing hydraulic models were used to determine channel capacity and discharge requirements to generate overbank flows for those reaches of the river covered by the models. In addition, a normal-depth computation analysis was conducted for the 1914 cross section and the 1998 resurveyed cross sections. Water surface elevation was estimated for a range of flow events up to the channel capacity for the 1914 cross sections and for maximum operating levels for the 1998 cross sections and existing hydraulic models.

Geomorphic data for the study reach were obtained from the CDC 1914 survey of the river and its flood basins and floodplains. For the 85 cross sections surveyed in 1914, morphometric data, including thalweg and top-of-bank profiles, channel widths and depths, bankfull stage, and width-depth ratio were obtained. Resurveys of the selected 1914 cross sections enabled changes in channel morphometry to be evaluated, including changes in channel planform (sinuosity and length).

No sediment transport analyses were conducted for this study. However, field sampling of the bed and bar sediments, visual observations of the study area, and information from existing reports (Cain 1997, Corps 1993) enabled some generalizations to be made about existing sediment transport and deposition.

The only previous source of site-specific descriptions of existing riparian vegetation is contained in Cain (1997), which covers Reach 1. Otherwise, existing and historical spatial distribution of riparian vegetation types in the study area was obtained from the results of the literature review and detailed mapping from aerial photographs contained in the companion report, *Historical Riparian Habitat Conditions of the San Joaquin River* (Jones & Stokes Associates 1998). Information on soils and groundwater conditions that may affect riparian vegetation were obtained from published reports, surveys, and maps. Surface soil salinity conditions were observed in the field. Recent effects of herbivore and vegetation scour or removal were observed directly in the field, as were indicators of recent riparian colonization and other age classes.

Primary Findings of Hydrology and Geomorphology

Major influences on the San Joaquin River system include: (1) natural geologic features; (2) the development of water storage and transport projects; (3) over-pumping of groundwater, resulting in subsidence of the valley floor; (4) the construction of local levees and state flood control projects; and (5) sand and gravel mining. The study provides an analysis and description of each of these influences and their primary effects on the river system.

Geologic Features

The San Joaquin River enters the Great Central Valley, an asymmetrical basin whose axis is offset to the west side of the basin. The basin lies between the crests of the Sierra Nevada and the Coast Ranges and extends from the northern boundary of the Tulare Lake basin to the Sacramento–San Joaquin River Delta near Stockton. The bulk of the flows in the river are derived from rainfall and snowmelt in the Sierra Nevada.

At the downstream end of the study area, base level control is exerted by the Merced River alluvial fan that has prograded out into the valley. Although there is good geological evidence that the entire basin is slowly subsiding, the fan appears to be maintaining base level for the upstream reach of the San Joaquin River at a constant elevation, at least within the period from 1914 to the present (Table 4.5). Over a longer period of time, the anabranching river system located within subreaches 4A, 4B and 5 argues for a rising base level (Knighton and Nanson 1993, Nanson and Knighton 1996, Nanson and Huang in press).

The flood basin of the San Joaquin River (Hall 1887) (Appendix D), which is characterized by the anabranching channel system made up of the mainstem river and the major sloughs, comprises subreaches 4A, 4B, and 5 (i.e., Merced River to Sack Dam). Historically, rainfall and snowmelt floods were conveyed through the flood basin and floodwaters were reported to stand in the overbank areas for 3–5 months per year. Sediment transport continuity was maintained by the hydraulically more efficient anabranched channels (Nanson and Huang in press).

The river in subreach 3 (Sack Dam to Mendota Pool) was historically a relatively low-sinuosity (Table 4.2), single-thread, meandering channel that was bordered to the west by an alluvial terrace and to the east by the distal margins of the coalesced eastside alluvial fans. The extent of the historical floodplain has also been limited by the construction of local levees and irrigation canals, but can be approximated by the Federal Emergency Management Agency 100-year floodplain (Figure 1.2). The floodplain was primarily located to the east of the river in subreach 3.

The river in subreach 2 was historically highly sinuous. The combined effects of the bifercation structure at the head of the Chowchilla Bypass, the low slope of the river because of the high channel sinuosity, and, possibly, the backwater effect of Mendota Dam, are responsible for the severe aggradation in this reach of the channel. The upstream end of subreach 2, Gravelly Ford, marks the downstream terminus of the terraces that flank the river and confine flood flows.

The river in subreaches 1A and 1B is characterized by a low-sinuosity meandering steam, flanked by three terraces, as high as 40 feet above the present riverbed. Extensive aggregate extraction has in many areas caused the formation of a multichanneled river. Flood flows are confined by terraces that flank the river.

Water Storage and Transport

The development of water resource projects with the basin commenced about 130 years ago. Friant Dam, forming Millerton Lake, and other dams constructed on the eastside tributaries by the Corps since the late 1940s have significantly altered the peak flows and the flow durations within the study reach. Except under flood flow conditions, extensive reaches of the river below Friant Dam are dry for most of the year. The Delta-Mendota Canal, in operation since the mid-1950s, maintains a perennial flow of imported Delta water in the reach of the river between Mendota Pool and Sack Dam.

An order of magnitude reduction in higher-frequency flood events (2-, 5-, 10-year flows) has occurred since the construction of Friant Dam. However, more limited reduction of lower frequency events (100-year or greater) still poses a flood threat to the system that was designed to provide a 50-year level of protection. In the post-Friant Dam period, there have been order of magnitude reductions for different seasons in the mean daily flows as well.

The imported flows from the Delta-Mendota Canal at Mendota Pool do not have the scour potential to remove the riparian vegetation supported by these flows, but they do have the ability to transport and deposit considerable volumes of sediment, primarily sand, in the downstream subreaches.

Subsidence

Commencing in the 1920s, significant overpumping of groundwater caused up to 30 feet of valley floor subsidence to the west of the river. Within the study reach, from 1 to 6 feet of subsidence has been documented. Subsidence appears to be having an adverse effect on the downstream elements of the Eastside Bypass system, but there is not unequivocal evidence that it is affecting the mainsteam river and the sloughs.

Local Levees and Flood Control Projects

Local levees and flood control projects were completed along the river between about 1915 and 1930 by local landowners. Between 1959 and 1966, the State of California constructed the Eastside Bypass flood control project, including the Chowchilla Bypass Bifurcation Weir, with assistance from the Corps. Non-project private levees are located between Chowchilla Canal and just upstream of the Mariposa Bypass near Los Banos.

These projects have significantly modified the distribution of flood flows within subreaches 3, 4, and 5. Routing most flood flow into the Chowchilla and Eastside Bypasses, construction of local levees, and importation of Delta water have effectively resulted in reduced flood-carrying capacity of the river channel between Chowchilla Canal and Sand Slough. Where historically the flows debouched into the west basin at the head of subreach 4A, most floodwaters are now routed into the Eastside Bypass, thereby eliminating all flood flows from subreach 4B. Where historical flood flows entered the east basin at Lone Willow Slough (near the present day Chowchilla Canal at lower reach 2) and other sloughs downstream, most flow is now routed into the Eastside Bypass via the Chowchilla Bypass inlet and the canal at the Sand Slough bifurcation weir. From a practical point of view, the San Joaquin River has been rerouted at the Sand Slough control structure out of the historical river channel and into the Eastside Bypass at least as far downstream as where the Mariposa Bypass returns flow to the mainstem river.

The vegetation that has become established in the channel in subreach 4A because of the absence of flood scour or perennial flows increases the hydraulic roughness in this reach and exacerbates sediment deposition, thereby affecting channel capacity. Very limited distribution of flood flows in subreach 4B has allowed the channel to narrow significantly. Sediment deposition within the lower reaches of the Eastside Bypass has required the periodic removal of sediment to maintain its hydraulic capacity. Significant sedimentation and aggradation of the channel in the reach just upstream of the bifurcation weir have also occurred.

Sand and Gravel Mining

Extensive in-channel mining of sand and gravel, in combination with reduced inflow of sediment from upstream of Friant Dam and Little Dry Creek, has resulted in severe channel degradation between Herdon and Friant Dam. What was historically a single-thread, low-sinuosity, meandering river has become a hydraulically disrupted flood conveyance system composed of single-channel segments, multi-channeled segments, and breached wet pits.

Primary Findings of Vegetation Conditions and Trends

The combined effect of multiple projects altered the hydrology of the river and reduced the magnitude of flows, which subsequently restricted the vertical range and geographic extent of alluvial processes that support riparian vegetation and promote its regeneration. Hence, the geographic extent of potential future riparian vegetation is considerably smaller than the current distribution of mature riparian habitats.

Vegetation Regeneration

The consequence of reduced floodplain inundation frequency, depth, and duration is a significant reduction in the potential for riparian vegetation to establish on new surfaces through overland seed dispersal or rewetting of secondary channels, sloughs, and ponded depressions. Throughout most of the study area, saplings or young trees were rare to absent on many floodplain surfaces that otherwise supported mature woodland types. Where seedlings and small saplings were observed, they occurred on recent sand and silt bars within a narrow vertical range within 0.5 to 2 feet above the low-flow channel water surface.

Conversion of Riparian Habitats

Conversion of riparian habitats to agricultural uses occurs over a large expanse of the historical riparian and marsh floodplains and basin lands of the river, but most of the areal extent of agricultural reclamation apparently predated the major changes in river hydrology caused by Friant Dam and the flood bypass system. However, within and along the riparian corridor, closer to the active channel of the river and major sloughs, expansion of agricultural and urban development flanking the river, as well as more recent recreational land uses, have in more recent decades encroached laterally further into the active floodplain of the river.

Vegetation Encroachment within River Channel

Channel clearing for flood control purposes is a minor factor limiting riparian vegetation in the active channel in the past 15 to 30 years. Riparian vegetation on floodplains flanking the active channel does not appear to be substantially affecting floodway capacity on most of the river. The most congested sites are where intermittent flow is found in combination with moist surface conditions on the channel bed during the growing season, thus promoting the growth of sandbar willow and giant reed across the entire channel cross section at some sties.

Soil and Shallow Groundwater Conditions

Boron and salinity levels in soils and shallow groundwater are potentially a limiting factor for the recruitment of riparian vegetation within the lower study reaches of the river. The effects of high surface concentrations of boron and salinity, which are naturally occurring conditions, may be magnified by groundwater overdraft east of the river and the near absence of overbank flow over most of the historic floodplain.

Recommendations

Chapter 6 concludes with a series of recommended approaches and concepts for enhancement and expansion of riparian habitat using three primary approaches: conservation of existing resources, including forest nodes and active floodplains; innovative management of the river corridor, such as altering the release pattern of flood flows to promote natural regeneration; and site-specific revegetation projects. Chapter 7 recommends additional data needs and focused studies to resolve uncertainties about the feasibility and efficacy of potential riparian habitat restoration measures, such as how sediment transport in the river may be affected by modifying the management of moderate flood flows below Friant Dam and the bypass system bifurcation weirs.